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JANUARY, 1889.

(Covering the months October, November, December, 1888.)

TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

SPECIAL MEETING, NOVEMBER 13TH, 1888.

SUBJECTS:

The Gaiffe-Bristol Meter for Direct and Alternating Currents.

By WILLIAM E. GEYER.

The Hitchcock Magnetic Coil and the Hitchcock Integraph.

By H. ARSANG-ARAKANOWICZ.

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Secretary's Bulletin.

The fifth volume of the Institute Transactions was completed with the issue dated September, 1888. A revised edition of the volume made up of printed sheets, corrected by the authors, consecutively paged and thoroughly indexed, will be ready for distribution to all members in good standing in a few weeks. Arrangements may be made in advance with the Secretary for binding the volume in half morocco with cloth or paper sides, as preferred, at an expense not exceeding $1.25. The first four volumes may also be bound in one at the same price, making a book nearly as thick, provided the numbers are returned to the Secretary for that purpose. Twenty-five cents should be enclosed for return postage, otherwise the book will be sent by express.

The Editing Committee has decided to begin the sixth volume with the year 1889, in order that the date of the volumes will hereafter coincide with the calendar year. This involves no omission of matter, the proceedings being recorded continously, and the current issue for January actually covers the apparent hiatus between the September and January issues. It was also decided that the monthly numbers be hereafter issued as the permanent and official publication of the Transactions, so that in future it will be necessary that they be carefully preserved by those who desire to keep a complete file.

At the regular monthly meeting of Council, held December 4th, a letter was read from the officers of the Institution of Civil Engineers, London, inquiring if any of the Institute members expected to visit Europe next season, in order that arrangements might be made to render their stay in England as pleasant and useful as possible. The Secretary was instructed to confer with

the Secretary of the American Society of Mechanical Engineers, in order that the different engineering associations might act in unison, thus obtaining special rates and accommodations, which would be mutually beneficial.. If 150 passages are secured, the excursion rate from New York to Liverpool will be fixed at $110, with a special steamer by the Inman line. A suitable circular will be prepared in a few days, giving all necessary details. Since the meeting of Council a letter of similar tenor has been received from the Society of Arts, London.

The following gentlemen were elected to associate membership, their applications having been properly endorsed:

Victor Nicholls, Electrician and M'g'r Vancouver Electric Ill'g Co., (Ltd.) Vancouver, B. C.

H. Eugene Chubbuck, Manager and Electrician, Champion Electric Light Co., Springfield, O.

The following associate members were transferred to full membership upon recommendation of the Board of Examiners:

O. B. Shallenberger, Pittsburgh, Pa.
Dr. Leonard Waldo, Lockport, N. Y.

At the 30th meeting of the Institute, held December 18th, a paper was read by Mr. W. J. Jenks, Member; Director of the Edison Standardizing Bureau, on "Six Years Practical Experience with the Edison Chemical Meter."

At the 31st meeting of the Institute, held January 8th, a paper was read by Mr. E. G. Acheson, Member; Electrician of the Standard Underground Cable Company, on "Lightning Arresters, and the Photographic Study of Self-Induction."

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

VOL. VI. New York, January, 1889. No. 1.

Covering the months of October, November and December, 1888.

SPECIAL MEETING.—EXHIBITION EVENING.

The twenty-ninth meeting of the American Institute of Electrical Engineers met on the 13th of November, at 8 P. M., at the College of the City of New York. Mr. Ralph W. Pope, the Secretary, called the meeting to order and said:

I received a letter of regret from President Weston to-day saying that he would be unable to be present with us this evening, and trusting that we would have a pleasant and successful evening, of which there is no doubt. It will be incumbent upon you to appoint a chairman for the evening, and I am ready to receive nominations.

On motion of Mr. T. C. Martin, Captain O. E. Michaelis was chosen Chairman. Captain Michaelis, on taking the chair, said:

Gentlemen: I am very much obliged to you for this mark of your kindness. At this first meeting of the Institute for the current working year, we may especially congratulate ourselves upon having papers presented to us in such a very desirable form. We have here an opportunity for properly illustrating papers, and I am sure we are all very thankful indeed to the officers of the College who have extended these facilities to us. As is our custom, there will be no business transacted this evening except the reading of the papers and the discussion thereupon. The first paper of the evening is on "The Geyer-Bristol Meter for Direct and Alternating Currents," which the author will read. It is needless for me to introduce this gentleman to you. He is a graduate of this institution, and for the past twenty years has been pupil and coadjutor of Professor Morton of the Stevens Institute.

Professor Geyer then read the following paper:

THE GEYER-BRISTOL METER FOR DIRECT AND ALTERNATING CURRENTS.

BY PROFESSOR WILLIAM E. GEYER.

In the meter about to be described we make use of the heating effect of the current. Electric measuring instruments depending on this heat effect are not new. In the Cardew voltmeter we have an application which has found much favor. Here the current of greater or less strength traverses a long, thin wire, heats it more or less, and the direct expansion is a measure of the current, and indirectly of electromotive force.

In an ammeter it is necessary to keep down its resistance, and I therefore doubt whether direct expansion can be usefully applied for this purpose; for the actual elongation of a bar of metal even when raised through a considerable range of temperature is very small.

In the familiar compound bar we have a case where a very small actual elongation produces a relatively very great lateral displacement.

I think I shall best be able to explain to you our meter, by recalling to your minds this old device. In the simplest compound bar, two strips of metal which have different co-efficients of expansion are securely soldered flat-wise along their entire length. Brass and steel are metals frequently taken. On heating, the brass expands more than the steel, and in consequence the bar bends, becoming convex on the side of the brass. When such a bar is heated by the passage of the electric current, it will deflect, and this deflection may be made a measure of the current. The disadvantage of such an instrument would be that atmospheric changes of temperature would also cause deflection, so that troublesome corrections would have to be introduced.

In our meter we also use a sort of compound bar, but eliminate at once the effect of surrounding temperature by taking metals whose co-efficients of expansion are the same or sensibly equal; in fact we take the same metal. Our first form of construction was as follows: A wire of german silver is laid upon a strip of german silver of considerably greater cross-section and radiating surface. The wire and strip are soldered together at

one end; separated for the remainder of the length by a film of mica, then tied together at frequent intervals with silk or other insulating material, and suitably supported or clamped at the unsoldered end. If now a current, either continuous or alternating, is allowed to enter the strip at one end, it runs along its length, there enters the wire, and leaves the instrument from the other end of the wire.

For a given current in the wire, on account of its greater resistance and also on account of its smaller radiating surface, the wire becomes hotter than the strip. In consequence of the difference of expansion, the bar bends, becoming convex on the side of

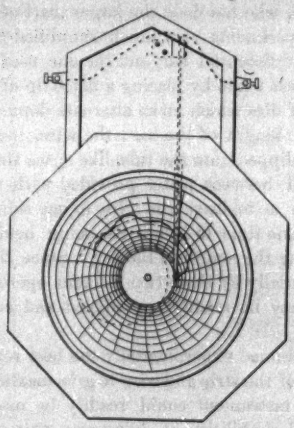


Fig 1

the smaller conductor. This combination we call a differential bar.

We would also state that inasmuch as the results obtained by the use of this instrument are due to the excess of the heating effect of an electric current upon one portion of the bar or its equivalent over the other, it is in a measure immaterial to the principle of the invention whether the current which produces the differences in temperature be caused to heat the two parts directly or indirectly. For example, the more expansible part, in lieu of being included directly in the circuit may be arranged in close proximity to, but insulated from, a wire or conductor which

is heated by the current. The other part or element may be in the circuit or not; but in either case formed or arranged to be less sensibly heated than the other.

It will readily be seen, however, that to heat one or both of the parts of the device in this manner would be clearly equivalent to connecting them both in series in an electric circuit. Unlike the case where magnetic action is employed, the force here available is very considerable, so that to make the instrument self-recording it is only necessary to attach an inking device to the free end and move in front of it a properly ruled chart. In this respect we have no difficulty whatever. My associate, Professor Bristol, who has done the larger part of the work, has since our first experiments very much simplified the method of constructing the differential bar, and the one used in the instrument exhibited was made by placing a flat strip of german silver between a pair of dies which make alternate depressions and elevations along the length of the bar; the wire, insulated with asbestos was then slipped into the tube-like space thus formed, and the whole pressed between plates provided with grooves of the proper depth, so as to leave the wire to one side of the centre line and at the same time to insure its being held firmly by the little bridges along the length of the bar. Since the bars can be constructed essentially by these two machine operations it is evident that they may be readily reproduced and at a very small cost.

We have determined experimentally the best relation between the cross-section of the strip and wire to give maximum deflection. We believe the instrument could readily be made integrating but doubt the desirabilitity of doing so. Our reason for this could probably not be better expressed than in the words of an eminent engineer, Mr. Charles E. Emery, in his paper on "Heating Cities by Steam," before the Franklin Institute, which we quote as follows :—

"It was at first considered unfortunate that a reliable meter could not be obtained, which, like a water meter, would show by differences of reading the quantity of steam used for the interval between observations directly without calculation, and without expense of maintaining a time register at each location, and of integrating the charts afterward. This system, however, proved a blessing in disguise. The greatest difficulty in settling with consumers lies in the fact that employés waste the steam. This is particularly the case during the heating season, when steam for

various uses is left on continuously during nights and Sundays, thus increasing the time of consumption from, say, 60 hours a week to 168 hours. In many cases, too, the rate of consumption keeps uniform during the night as well as during the day, so that it is an easy matter to more than double the bills. The consumers at first naturally lay the blame to the steam of the company, but the meter charts have been the means of enabling the company to satisfy consumers, when, and to what extent, the increased bills were due to mismanagement on their premises."

Substitute electricity for steam, the reasoning will apply perfectly to our case.

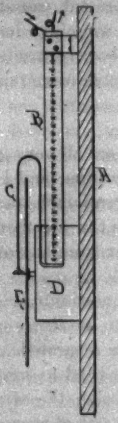


Fig 2.

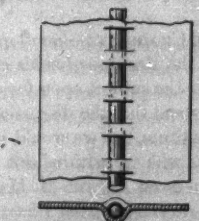


Fig. 3.

Figure 1 is a general view of the differential bar, mounted in a case with inker and recording dial.

Figure 2 is a side view of the important parts, the case being removed.

- A. Supporting framework.
- B. Differential bar.
- C. Inking pointer attached to bar.
- D. Clockwork moving dial.
- E. Revolving dial for receiving record.

Figure 3 shows a small portion of the bar and a cross-section on an enlarged scale.

Professor Geyer then explained the practical operation of the meter as follows :

I will just for a moment call your attention to the instrument. You will see it has been recording for the time you have been here. By the kindness of the authorities here, I have been furnished with current as you see which here supplies a rack of lamps, and as I turn the lamps off and on, you can notice that the pointer gradually goes down or up, leaving its record. The pointer does not respond instantly to changes of current, but, as in actual use this record is spread over days, and in fact probably over weeks and months, this, I think, would not be a serious inconvenience. The clock that we have here at present, causes that dial to rotate once in twelve hours. Of course we might have a clock rotating faster or more slowly. If it had been convenient, I should have gotten one where the dial moved much more rapidly.

DISCUSSION.

THE CHAIRMAN :—Gentlemen, I am sure we are all very grateful to the Professor for his clear and able exposition, and I now declare the subject open for discussion. The gentlemen present understand that the discussion is not limited to the members of the Institute, but we would be very glad to hear from any of our friends who are with us this evening.

PROFESSOR ALFRED M. MAYER :—I ask one question merely to elucidate farther what I have heard, that is as to the linear quantity or distance that the axis of bar and wire are separated.

PROFESSOR GEYER :—I have not estimated or tried to measure exactly what that distance is. Our idea is to bring the wire of course very close to the centre line of the strip, but of course not coinciding with it. I have several bars here finished, which the gentlemen are at liberty to examine.

DR. SCHUYLER S. WHEELER :—I would like to ask Prof. Geyer the effect of changes of atmospheric temperature on the meter.

PROFESSOR GEYER :—We have experimentally tried to find out whether atmospheric changes of temperature did affect it, by taking it in the winter time from an ordinary heated room into a hall-way or passage-way where the temperature was below freezing, and then passed the same current (as indicated by another instrument through it, without being able to detect any difference in the reading. It is the difference of the temperature in the two bars, which counts, not the actual temperature of either one.

MR. FRANCIS B. CROCKER :—I would like to ask Professor

Geyer if the moisture in the atmosphere has any effect. The same question arises in regard to the Cardew volt-meter and I have never heard it answered. On a moist day for example, the wire would lose its heat more quickly than it does on a very dry day. In other words, would not the difference in temperature be greater on a dry day, than on a wet day?

PROFESSOR GEYER:—On that point we have not made any experiments. I should judge from general principles, as it is simply the difference of temperature between the two bars that the case would be analogous to the case that I mentioned before, of putting the instrument into the warm room and then into the cold room; the moisture in the atmosphere if it has any effect, being simply equivalent to increased heat or increased cold around the instrument. I should imagine the results would be negative.

MR. CARL HERING:—I would like to ask whether it would make any difference with this instrument whether the current were direct or alternating.

PROFESSOR GEYER;—It would make no difference whether the current were direct or alternating. What we measure is the heating effect of the current. We say an alternating current is equal to a continuous current for all practical purposes when it produces the same heating effect.

In answer to a question by Dr. Vander Weyde, Professor Geyer said:

The instrument, as shown here, is intended only as an ammeter, although we believe a volt-meter can be made. In this case it is necessary to introduce very high resistance, and we think we can accomplish this by using a very fine wire, bent backward and forward a great number of times, and then lay that as a flat disc upon the other strip. I found the latter would be heated by its proximity to the heated wire, but there would be no difficulty of course in passing the current through this strip in addition to passing it through the wire.

DR. VANDER WEYDE:—The objection to using the principle of expansion by heat as a volt-meter is that currents of a very small number of amperes have no heating effect.

PROFESSOR GEYER: The question as to how many volts a Cardew volt-meter will indicate is to my mind simply a question of proper adjustment of parts. Thus, for instance, at the Stevens Institute we had occasion last summer to measure directly the electromotive force of a Westinghouse alternating machine.

We wanted to measure, if possible, directly; without any multiplying devices; say from 10 to 500 volts, we therefore constructed a volt-meter sufficiently long—in fact it was two stories high, and we had no difficulty whatever in getting very large deflections for 10 volts—that is as low as we cared to go, and we made our pointer go around nine times for 500 volts. To make no mistake in counting the nine turns we had a secondary dial, which as on a common clock rotated one division for each revolution of the other dial.

Mr.. C. O. Mailloux:—I would like to ask Professor Geyer what is the rule, or law, or function, of the deflection of the strip with the rate of current.

Professor Geyer:—In some respects it may be unfortunate that the deflections are not proportional to the currents. It would hardly be expected. As we all know the heating effect varies as the square of the current, so if I double my current I have four times the heat produced, but then the bars will lose their heat much more rapidly when they are at a higher temperature. The deflections are not then as the square of the current, but as some intermediate function. I have plotted out some

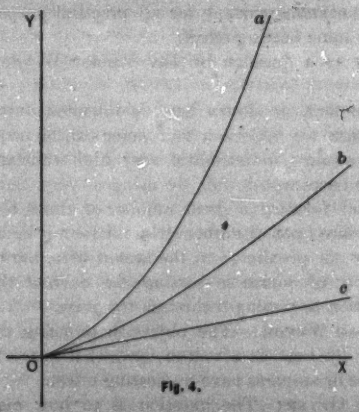


Fig. 4.

curves, and if I had thought of it, I might have drawn them on the board. I have not a curve here, but I might represent it, making a guess at it. Let the abscissæ (referring to a sketch, Fig. 4) represent amperes, and let the elevation represent deflec-

tions. If there were no increased loss of heat due to increased radiation from increased temperature, then of course our curve would be one rising quite steeply up that way as O *a*, (illustrating), and of course if the deflections are proportional to the current; our curve would be a straight line as O *c*. As a matter of fact it is a curve between this straight line and this curve which rises as steeply as the amount of heat due to the C^2 R law would require, and is represented in the figure by O *b*.

In reply to a question put by Mr. Wolcott, Professor Geyer continued:

The circles drawn on this card are ampere circles. Gentlemen can see from noting the relative distance of these concentric circles what the rate of increase is for increased current. You will at once notice at the outside of the disc the distance between two concentric curves is greater there, that the instrument grows more and more sensitive as the amount of current on it is increased.

Mr. Crocker:—I would like to ask Prof. Geyer one question, which I think has an important bearing on all meters, that is the amount of current consumed compared with the amount of current that is measured—that is to say the efficiency of the meter. I think these meters working by the heat produced—for example Professor Forbes's meter, and to a certain extent the Cardew volt-meter consume rather a large quantity of current in proportion to the current that they measure. For example, when ten lamps are in circuit, using, say ten amperes—I would like to ask Prof. Geyer what the drop over the meter would be in volts.

Professor Geyer:—I agree with the gentleman that the question of resistance is a very important one indeed, and we have aimed to keep the resistance of the ammeter low. The resistance of the bars which are there exhibited, is about .06 of an ohm. We believe it could be brought much lower, possibly by selecting other metals. Probably the length of the bar might also be much shortened. When I tell you the resistance of the instrument is so much, you can calculate at once for any given current what the loss of energy is in the meter, compared with the consumption of energy in the lamps.

Dr. Wheeler:—What is the ampere capacity of that .06 ohm strip?

Professor Geyer:—That strip will carry currents up to 20

amperes and possibly greater. We have not urged it beyond that point.

DR. VANDER WEYDE:—You can make them to any capacity, of course.

PROFESSOR GEYER:—They can be made to any capacity by making the cross section of the pieces greater.

DR. VANDER WEYDE:—I confess that the low resistance is a great advantage in your arrangement.

PROFESSOR GEYER:—In the Cardew instrument of course great resistance is not an objection. It has always, to my mind, been one objection to the Forbes meter, that it consumes relatively a large amount of energy. He uses a very small proportion of the heat produced to operate a little wind-mill. We might be said to use the whole heat produced.

MR. TOWNSEND WOLCOTT:—With regard to the voltmeter which was drawn on the board, the reason I asked the question was because it would require considerable length of wire, and I should judge the self-induction would be very high. That seems to be the trouble with using a straight wire.

PROFESSOR GEYER:—I think if the wire was laid zigzag the self induction would for that very cause be eliminated.

THE CHAIRMAN:—Is there any further discussion, gentlemen? I see we have with us this evening our friend Dr. Moses, and I am sure we should all be pleased to hear from him in regard to this very interesting subject.

DR. OTTO A. MOSES:—I regret to say, gentlemen, that I came late this evening. The subject is a very interesting one. There are one or two questions that may be a little at random, but they are simply through ignorance, not having heard the earlier part of Professor Geyer's lecture. Is there any superior advantage in having different radiating areas of the same metal over different radiating areas of different metals?

PROFESSOR GEYER:—The great point is that we have two metals whose coefficients of expansion are equal, so that simple atmospheric changes shall not cause the bar to deflect. If then you select two different metals, which, however, have the same coefficient of expansion, it will not alter the action of the instrument. The object of getting more radiating surface is to get a greater difference of temperature between the one conductor and the other conductor.

DR. MOSES:—One farther question. Do you believe it is pos-

sible to keep the surface at the same equal degree of polish, and in that way to be able to get equal ratios of radiation? Take german silver; the oxidation that will take place upon it from the increased radiating area of one side may in that way affect its accuracy after a while, may it not?

PROFESSOR GEYER:—I think it would affect the rate of variation to a slight extent. We propose to use such a cross-section that the wire shall never lose its polish from simple heat generated in it. It would thus only lose its degree of polish gradually if subjected to severe treatment from without, say strong acid fumes. Ordinary atmospheric changes do not seriously affect german silver.

DR. MOSES:—In the case of alternating currents, have you considered the electric density, so to say, of the conducting body in relation to the differences of areas. That is a question that has recently been brought forward. Have you had time since its suggestion to look into the matter?

PROFESSOR GEYER:—I must confess my ignorance and ask the Doctor to explain what he means by electric density. Then perhaps I shall be able to answer.

DR. MOSES:—I mean by that, the fact that in conductors of different areas of cross-section there have been found to be certain parts, that, by counter electromotive force set up within the body of the conductor itself, have been found to be like the central part of rods in mechanical strains, they do not have the same ratio of conductivity owing to the sudden alterations of the current, the current not seeming to be able to permeate as it were to the centre. This difference in area might in some way or other affect the amount of current that would pass over the conductor wire and surface and in that way somewhat effect the heat radiation.

PROFESSOR GEYER:—I thank the Doctor for his clear explanation. I can only answer it as far as this—that I have lit up lamps with a continuous current and noted the deflection of the instrument, then heated them up to the same degree of brightness as measured on the photometer and noticed the deflection when they were lighted by an alternating current of 16,000 alternations per minute and could notice no difference in deflections.

THE CHAIRMAN:—The Chair hears no further remarks and we will therefore proceed to the next subject.

We are fortunate in having with us this evening a distin-

guished gentleman from abroad, a prominent mathematician, a well known contributor to that peerless European technical journal *La Lumière Electrique*, and a gentleman who has an important official connection with the electrical department of the forthcoming Paris exhibition. He will exhibit to us one of his own many inventions, an invention that I know will engage the breathless attention of a New York audience because I may call it in the vernacular an apparatus for dispensing with "cranks."

I have the pleasure of introducing to you Mr. Abdank of Paris.

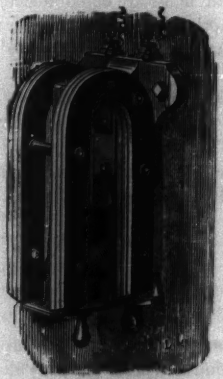
MR. ABDANK :—Mr. Chairman and gentlemen ; before I begin I must crave an indulgence. I am only a beginner in knowledge of the English language, and my vocabulary has only a few words and it is the first time that I have spoken in public in your language.

Mr. Abdank then read the following paper :

THE ABDANK MAGNETIC CALL, AND THE ABDANK INTEGRAPH.

BY B. ABDANK-ABAKANOWICZ.

Permit me to speak first of a small improvement in magnetic calls. The instrument that you see here, figures 1 and 2, was constructed as long ago as 1882, when calls for telephones were wanted everywhere. The principle of this call is extremely simple. For producing electromotive force we are obliged to move a coil through a magnetic field. I fix my coil at the end of a straight spring, the other end of which is solidly held by the



THE ABDANK MAGNETIC CALL; FIG 1.

support. On the same support are fixed two magnets that create the magnetic field. If I move the bobbin from its neutral position, thus bending the spring, I am storing up the muscular energy of my hand in the spring. If I remove my hand this energy is restored in a series of oscillations of the bobbin through the lines of force. In this way an oscillatory current is produced in the closed conductor, and the mechanical energy reappears on

the other side in the form of the movements of the bell striker. I have made similar calls of different sizes, beginning with half the size of this one (about four inches), up to others where the diameter of the bell was three or four feet. As the electromotive force developed is very high the working distance is very great. This small one can ring a bell to a distance of over 100 miles over an ordinary telegraph wire. We have tried successfully larger calls on lines over 600 miles.

The apparatus is an old one, and I give the short description of it only as an introduction to some theoretical remarks on its working. In this country, calls approaching to mine, based on the synchronous movement, were patented by Andrews and Watson. Mr. E. Meylen has lately made measurements in my laboratory, for the purpose of finding the curve of electromotive forces produced by the passage of the coil across the magnetic field, and this is the subject of my communication to-night.

If we admit that the instrument is symmetrically constructed, and that the magnetic fields are equal in strength, then the curve of induced electromotive forces must have a regular shape. We neglect also the retarding influence of eddy currents induced in the iron core.

We must have the greatest electromotive force in the middle, where the ratio of variation of the quantity of lines of force is the greatest.

The curve obtained by direct measurement was very different in shape, being as shown in figure 2.

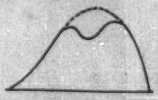


FIG 2.

This curve presents two remarkable features. First, we see a depression in the middle, where, theoretically, the electromotive force ought to be a maximum. The reason of this is to be found in the defective form of the iron core in the armature. The diagram figure 3 and the curves in figure 4 will clearly explain this.

This defect in the construction has a very bad influence on the the result, the greatest and most useful electromotive force being lost, as shown in the dotted line, figure 2, and the same defect was often found by me in different alternating current dynamos.

The second characteristic feature of the curve is in the shifting of its ordinates in the direction of the movement of the armature. Beginning from the starting point the curve is convex, and near to the other end, concave in relation to the middle ordinate.

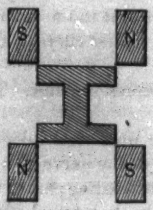


FIG 3.

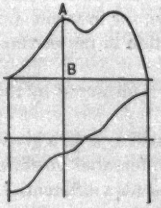


FIG 4.

When the armature moves backward the same deformation was remarked, but in opposite direction.

The electromotive force produced was always somewhat behind the time in which it ought to have been produced. We supposed at first that this was due to the retardation in the indication of the electrometer used for the measurement, but we found by different controlling methods that this was not the case, and that this retardation is probably due to the action of eddy currents induced in the armature core. As you see, the maximum points of the curve are not symmetrically placed. This proves that the magnets did not possess the same strength of magnetic field.

The method used for the measurement of the ordinates of these curves was very simple.

The variation of the magnetic field in the path of the armature was also found experimentally, and then controlled by direct integration of the curve of electromotive force.

The ballistic method was used for the measurement. This method allows of the measurement of the variation of the quantity of lines of force independent of the time. The total variation of the magnetic flux was found to be:

$$\Sigma\, d\, F = 5.1 + 10, \text{ (C. G S.)}$$

The mean current was 0.021 ampere. The mean power was 0.26 watt.

The curve of the variation of the magnetic field can be found directly from the curve of E. M. F., as before alluded to.

Every ordinate of the curve of E. M. F. is proportional to the ratio of the variation of the number of lines of force.

It is equal to the differential coefficient $\frac{d F}{d x}$

Let us consider the four curves in their relation. Every ordinate, for instance, A, B, figure 4, is proportional to the ratio of variation in the corresponding point of the second curve. This ratio is measured by the ratio $\frac{d y}{d x}$ where $d x$ represents time. The ordinate A, B, in a given scale, is equal to the numerical value of the differential coefficient. Every ordinate of the curve E. M. F. represents a differential coefficient of the corresponding part of the magnetic curve. The magnetic curve is simply the integral of the E. M. F. It is obvious that if the equation of the E. M. F. were given, it would be possible to find the magnetic curve by integrating this equation.

This integration can be performed mechanically by an integrating machine. There is one of these machines constructed in Zurich, by the celebrated constructor, Coradi. To perform the integration it is sufficient to follow with the tracing point the given curve. The integral curve is then mechanically traced by the instrument. (M. Abdank here exhibited his integraph and explained its action.) The integration of differential equations is a problem that we meet continually in the physical sciences. We perform an integration in determining the area of a given figure; also in determining the static moments and the moments of inertia, in calculating the shape of the elastic curve.

The planimeter, as you know, gives mechanically the area and the moments. The instrument that you see before you gives much more. It traces a curve that indicates how the integral increases. The curve is the integral curve, the applications of which are extremely numerous. You have seen one of these applications for the determination of the magnetic curve.

I am glad to have had the opportunity to present it to this electrical society, and, as it were, smuggle into your presence a mathematical instrument under the cover of an electrical application. And I do so because the apparatus interests me personally, being myself the inventor of it.

I must also crave your pardon for having addressed you in

English, of which language I am not at all a complete master, and I am ashamed, because that lack of knowledge is entirely contrary to my principles. I am of the opinion that every electrician ought to be able to speak English. He cannot be a good electrician without being a complete master of that language. Without an intimate acquaintance with the works of Faraday, he is not able to draw conclusions in a simple and logical manner from experiments. He cannot, without being in direct communication with the legion of workers in electricity who speak the English language and who have advanced electricity in this country to a point where it is 50 years ahead of that in Europe, I say, that without knowing it intimately, he cannot keep track of what can be done with that power of nature which we are all attempting to harness.

DISCUSSION.

THE CHAIRMAN:—I think we will all agree that Mr. Abdank speaks English well enough to have given us a great deal of information in a very brief time. The subject is now open for discussion, and as we have with us a number of distinguished college professors, I would advise that these gentlemen be requested to open the discussion. Will Professor Geyer favor us with any remarks?

PROFESSOR GEYER:—I would say that the Chairman has made it difficult for any one to reply, for he has called the gentleman distinguished and it looks very egotistic to get up first.

THE CHAIRMAN:—The gentleman was called upon by name. He is relieved from the charge of immodesty in that respect.

PROFESSOR GEYER:—I would just like to ask one question, in reference to one of the experiments the picture of which is on the middle blackboard, the current being an instantaneous current, whether it was attempted to make any corrections for the self-induction of the galvanometer coil. As I understand it, the current was just a momentary current.

MR. ABDANK:—The current was momentary relative to the period of oscillation of the needle.

PROFESSOR GEYER:—What I meant was whether the current really had time to develop its strength as to its electromotive force.

MR. ABDANK:—The difference would be small.

PROFESSOR GEYER:—I was more particularly interested in the subject because I had somewhat analogous experiments made under my direction when it was attempted to measure the electromotive force of an alternating machine where the alternations took place at the rate of 16,000 a minute and it was there done by causing the condenser to be charged and then at your pleasure discharging it also through a ballistic galvanometer.

MR. WOLCOTT:—Having been for some time interested in the study of integrating machines of various kinds and having invented some myself I can say that I never have seen anything which will approach this instrument which Mr. Abdank has shown us. The ordinary type of integrating machine which Mr. Abdank has spoken of will simply give a reading at the end of a given time—simply a single reading of the integral. We are all familiar, that is all who have given any study to the subject, with the apparatus of Professor James Thomson, Sir William Thomson's brother, which will integrate any expression involving a single variable. This apparatus, or rather a combination of several of them, will also integrate differential equations; but I never heard of any apparatus like this one we have seen to-night, which will trace out an integral curve, the ordinates of which are integrals of the ordinates of the other curve, and I would be very much obliged to Mr. Abdank if he could give us the principle of this machine. Has he any printed description of it?

MR. ABDANK:—I am writing out a description of the apparatus for a paper, and perhaps that will answer the gentleman's purpose. It will be published shortly.

MR. CARL HERING:—I would like to say, in behalf of Mr. Abdank, that one of the features of that instrument besides tracing the integral curve is that it can be used for solving numerical equations which, I understand, cannot be solved algebraically—equations of a high degree, 4th, 5th and 6th degree. The instrument will trace out a curve, the dimensions of which will give the values of equations of high degrees, 2d, 3d, 4th, 5th, 6th, and so on.

MR. WOLCOTT: Does that give all the real roots in one curve?

MR. ABDANK:—Yes.

PROFESSOR MAYER:—If the machine will do that it is a marvellous production of ingenuity and science. Charles Babbage, of England, gave his whole life to making a calculating engine. After he had perfected his difference engine, and the British

government would not supply him with means of bringing it out, he invented an analytical engine, of which you will find a description by the only daughter of Lord Byron, Lady Lovelace, which machine did just what this does. The construction of it would be so difficult that Babbage had not the means of bringing it out. If a machine so simple in its construction will do that, I can see that it is the most marvellous production of this age. I would like very much to understand it. Of course I only see it there, and I know nothing of the principle of it.

THE CHAIRMAN:—I understand, Mr. Abdank, to put it in plain language, for instance in solving any equation of the second degree, the instrument would describe a conic section, and so on, the cissoids and higher curves according to the nature of the equation.

MR. ABDANK:—Yes. (The speaker put an equation on the black-board). We have first the equation of the first degree which represents a straight line. Then I perform successive integrations (integration with the instrument). The first curve would be a parabola, and repeating that several times I arrive at a curve that will represent the first equation, and then I have all that I want by the intersection of that curve with the axis of abscissa. I have here in my book the solution of one of these equations and the solution of the equation of 3d degree only. (The speaker copied upon the black-board the equation from his book). With respect to the calculating machine of General Babbage—I know that machine very well. My instrument acts in a different way. The machine of General Babbage is only an arithmetical machine. It has nothing to do with differentials.

MR. WOLCOTT:—There is one more question I would like to ask Mr. Abdank. As has been said there are plenty of machines for performing integrations with respect to a single variable. So far as I know there has never been a double integration; that is one integration with respect to two independent variables, performed by mechanical means. I do not see how it is possible.

MR. ABDANK:—It is possible in special cases.

THE CHAIRMAN:—Is there any farther discussion? If not we will proceed to the next paper on the programme for which we are also indebted to Mr. Abdank, but a description of it will be given by our fellow member Mr. Carl Hering, of Philadelphia. As I understand it, it is a combined electrical and musical stenographic recorder and type-writer. (Laughter.)

MR. HERING:—Mr. Abdank thinks he does not speak English well enough to describe this apparatus. I believe you will all agree with me that he speaks English very well and it would be much better for him to describe it. The apparatus I will describe are the melograph and the melotrope. The melograph is an apparatus for recording what has been played on the piano, and the melotrope is an instrument for reproducing this music from the record made by the melograph. The melograph consists of a system of contact points or keys which are fastened under the key board of a piano and are so arranged that when a key is depressed, the contact is closed; these keys are then connected to an instrument like the ordinary Morse ink recorder, so that when each key is depressed a mark will be made on a strip of paper corresponding in position to the position of the note on the piano, and as each note is represented by a key and by corresponding recording apparatus each note will, on being played, be recorded on a strip of white paper like this, in the form of a dark line, which perhaps you can see. This paper is therefore a record of the notes that have been played by the player. It not only records the notes that were played, but the length of the line records the time during which that note has been held, so that it is not only a record of the note itself, but of the time of the note. This record is then passed through an intermediate apparatus called a perforator, the object of which is to perforate a piece of stiff paper with rectangular perforations corresponding to these lines of the melograph record. This is done by means of an electric apparatus which consists of a little square punch which travels up and down very rapidly. It is driven by an electric motor. I understand the lines on this paper are first run over with a puncturing pin. Then this paper is passed over a series of contacts. Wherever the paper is punctured, connection will be made, which connection will work this little punch at a place corresponding exactly to the place of this line on this record. In other words, this record on stiff paper is an exact counterpart of the other only that it is perforated with smooth rectangular holes, whereas this is originally merely a written record. This record is then ready for the melotrope—the reproducing apparatus. This melotrope is merely mechanical in its action. It would be rather difficult to explain it without models, but I will try to give a short description of the essential parts of it. The idea of the inventor in designing the re-

producing apparatus was to imitate as nearly as possible the motion of the finger. In ordinary mechanical piano players, the keys are merely depressed by a force which is constant, and in short, the whole apparatus is very mechanical in its action; but in this case the inventor has tried to imitate the motion of the finger; in other words he has tried to depress the keys softly, gently or with considerable force, to hold them down a longer or shorter time. Now this is accomplished in the melotrope, which is the apparatus Mr. Abdank will exhibit, by means of a long roller which extends over the length of the key board to be played upon. This roller has cut into it a number of grooves, the sides of which are slightly inclined. In this case the instrument is arranged for three octaves. There are 37 notes to be played. There are therefore 37 of these grooves. This roller (exhibiting a model) is being turned constantly in one direction and when that string is tightened it will pull this finger down. This finger rests on the keys, so that whenever this string is tightened this finger will be pressed down. The tightening of this string is performed by a mechanism which I will not attempt to explain now. It will suffice here to say that it is a little wedge which is run into this groove. The little wedge is actuated by levers which run over the paper. Wherever they come opposite to a hole, this little lever passes through the hole. In passing through the hole that end of the lever makes a motion which is transmitted to this little wedge. The wedge is pressed into this groove. That tightens the spring and pulls down the hammer. So that wherever there is a hole in this record the corresponding wedge will be pushed into the corresponding groove which will tighten that string and will press down the key and will hold the key down as long as there is the hole in this paper. I am told by a pianist that the pressure exercised by the finger in playing is sometimes as much as five pounds, so that these little fingers must come down each with a force of five pounds, and I understand that they can come down with greater force than that, because this apparatus can play even louder than a person can play. I might add that the apparatus does not automatically produce *piano* and *fortissimo* effects. Wherever *piano* should be played and wherever *fortissimo* should be played, it is written on the music, and the effects of *piano* and *fortissimo* are produced by a little lever on the side of the instrument. This little lever does nothing more than run these wedges toward the roller or from it.

If it moves them toward the roller, it is evident that the force with which this would be moved down would be much greater. If they are pulled away, the force with which this comes down is much less. This apparatus is only a model so that you will notice the want of a full bass. It can just as well be constructed for seven octaves.

DR. VANDER WEYDE:—How does the electricity act on that written paper?

MR. HERING:—It is punctured with a puncturing pin. It is necessary to go over this by hand.

DR. VANDER WEYDE:—It is just as easy to punch those holes mechanically as to puncture them by hand.

MR. HERING:—It is necessary to go over this by hand for this reason: Every player, however expert, will touch notes that he ought not to touch. They will all be recorded by this apparatus and it is necessary to have some one go over and erase those notes.

DR. VANDER WEYDE:—I beg your pardon, good players will not touch notes which they ought not to touch.

Mr. Abdank then played on his instrument the overture from Carmen and afterwards the Boulanger March.

MR. HERING:—There is something about this which will interest those of you who are musicians; you all understand that the notes are represented by certain positions on this paper. Therefore if you reverse this paper and pass it through the apparatus the wrong way the notes would be entirely different. A note which is three spaces above would then be three spaces below. The effect is rather curious. We will try it first and discuss it afterwards. The piece is the Minuet from Don Juan. It will be played first the right way.

Mr. Abdank then played the Minuet from Don Juan and afterwards played it by reversing the paper.

DR. VANDER WEYDE:—Now play it backwards.

MR. HERING:—It will sound like Chinese music played backwards. As just played—simply reversed—it was in minor, while it originally was in major, but the chords were perfectly correct.

Mr. Abdank then played the piece backwards; he also played a piece improvised especially for the melotrope. The improvisation was written in his labratory, and converted in one hour after he played it into the form ready for the melotrope.

THE CHAIRMAN:—Gentlemen, the subject is now open for discussion.

DR MOSES :—Would Mr. Abdank be so kind as to reverse the last piece ? My object in asking is to see whether the reversal of a piece cannot be the most accurate criticism of its correctness. It is a most interesting fact that music reversed in that way will produce a pleasant impression upon the ear. There is an analogous fact which may bring some light to bear upon this point. If you take a piece of paper and write simultaneously with both hands in opposite directions, then reverse the one that looks written backwards and look at both, holding the objects between the eye and the light so that the two writings will seem to be then in the same direction, you will find that they are written by the same hand. Now the reversal of music indicates correctness of the thought and the harmony in the first direction. And it may be possible, in that way to discover an accurate method of criticising the correctness of harmonies, or in other words what should be heard. There is some music which takes a very considerable musical education to appreciate. If that music when reversed becomes harmonious, then it is worth being heard, perhaps.

MR. MAILLOUX :—I understand that Mr. Abdank is a very modest person, and he tells us that he is not a performer on the piano, but I am told that he is something of a composer and that he has written pieces of more than passing interest. I should like to have him favor us with some of his own selections.

MR. ABDANK :—It is my namesake—another Abdank who is a composer.

THE CHAIRMAN :—I am sure we would all be delighted to hear Mr. Abdank, but I think it would be well to defer that pleasure to a future occasion. We still have something to do. We are here on the invitation of the authorities of the college, and Professor Doremus, in whose particular department we are now has thrown open the laboratories to our inspection. Perhaps it might be well for us to avail ourselves of this opportunity and show our appreciation of the kindness extended to us by visiting the laboratories, physical and chemical, before we adjourn finally to-night.

DR. WHEELER :—I move a vote of thanks of the Institute to Mr. Abdank and of congratulations upon his intelligent English.

MR. T. C. MARTIN :—In seconding that motion I should like to say that it was our intention to have relieved Mr. Abdank from the labor to which we have put him at the piano, but we began a little too late, and we found that to apply the electric motor it

would involve a reduction of about 20 to 1, the melotrope going at about a rate of 80 or 90 revolutions and the motor at the rate 1,800 or 2,000.

I think also our thanks are due to him not merely for the fact that he has given us such charming music but because also he has performed a feat which I believed to be beyond anybody's capacity. He has actually succeeded in compelling high science professors to discuss a common electric bell. That I believed to be almost beyond the range of possibility. I would like to say that Mr. Abdank has taken great pains in preparing himself for this evening and I can assure you that the work he has undertaken has been gone through by him with the utmost pleasure and I second the vote of thanks to him therefore most heartily.

THE CHAIRMAN :—The Chair thinks that it is eminently proper that a vote of thanks should be extended to our guests, for while it is not the custom to thank our own members for the pleasure and instruction given us—we deem that in a measure a sort of duty on their part if they have leisure and inclination—but for a stranger who comes here I think it is proper that we should thank him in this formal manner.

The motion was carried.

MR. MAILLOUX :—I move that the Institute tender a vote of thanks to General Webb, president of the College of the City of New York, for entertaining the Institute this evening, and also to Professor Doremus.

The motion was seconded.

THE CHAIRMAN :—You have heard the motion. I presume it is hardly necessary for me to put it. The Chair will announce its unanimous passage unless he hears a voice to the contrary. I have an announcement to make, which I make with very great pleasure indeed. We have had, I was going to say, a nibble, but I will say a very large bite at this most interesting subject of meters, and I announce that at our next meeting, which will be held on the 18th of December, and, through the courtesy of General Webb and Professor Compton and Professor Doremus, here at the college where we will have the same facilities that we had to-night for the experimental illustration of the subject, a paper will be read by Mr. W. J. Jenks, a member of the Institute, and present director of the Edison Standardizing Bureau. His subject will be "Six Years Practical Experience with the Edison Chemical Meter."

Adjourned.

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NAME.	ABBREVIATION.	PUBLISHED, &C.
Engineer.	*Engr.*	London, 163 Strand, weekly. £1.9.
Engineering.	*Eng.*	London, 35–36 Bedford St W. C.; weekly. £1.16.
Industries.	*Indust.*	Manchester, 70 Market St., weekly. £1.12.
The Electrician.	*Lond. Elecn.*	London, 1 Salisbury Court, E. C.; weekly. £1.2.
The Telegraphic Journal and Electrical Review.	*Lond. Elec. Rev.*	London, 22 Paternoster Row, E. C.; weekly. £1.1 8.
The Electrical Engineer	*Lond. Elec. Engr.*	London, 139–140 Salisbury Court; weekly, 17s. 4d.
Nature.	*Nat.*	London, 29 Bedford St., W. C.; weekly, £1.8.
India Rubber & Gutta Percha & Electrical Trades Journal.	*I. R. & G. P. Jour.*	London, 115 Finsbury Pavement, E. C; monthly. 15 shillings.
The Electrical Engineer	*N. Y. Elec. Engr.*	New York, 11 Wall Street; monthly, $3
The Electrical World.	*Elec. World.*	New York, 168–177 Potter Building; weekly. $3.
The Electrical Review.	*N. Y. Elec. Rev.*	New York, 13 Park Row; weekly. $3.
The Electric Age.	*Elec. Age.*	New York, 5 Dey Street; semi-monthly, $1.50.
Modern Light and Heat.	*Md Lt. and Ht.*	Boston, 178 Devonshire St.; weekly, $3.
Western Electrician.	*West. Elecn.*	Chicago, 6 Lakeside Building; weekly, $3.
Journal of the Franklin Institute.	*Jour. Fhln. Inst.*	Philadelphia, Franklin Institute; monthly, $5.
Science.	*Science.*	New York, 47 Lafayette Place, weekly, $3.50.
Scientific American.	*Sci. Am.*	New York, 361 Broadway; weekly, $3.
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Mechanics.	*Mech.*	Philadelphia, 907 Arch St.; monthly, $1.
Railroad Gazette.	*R'd. Gaz.*	New York, 73 Broadway; weekly, $4 20.
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Street Railway Journal	*St. Ry. Jour.*	New York, 113 Liberty St.; monthly, $2.
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